An Acoustic Analysis of Chinese and English Vowels

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Abstract

This study compares the articulation of two pairs of similar vowels in Mandarin Chinese in Taiwan and American English. Four Taiwanese learners and four native speakers of American English were recruited to produce five vowels for each language. Acoustic vowel qualities of formant one (F_1) and formant two (F_2) values were measured and analyzed. Results show that Chinese English and American English are different in vowel height and frontness. Pedagogical implications are provided for EFL teachers to help Chinese learners improve their pronunciation.

Key words: acoustic phonetics, pronunciation teaching, interlanguage analysis

Introduction

Selinker (1972) first introduced and defined interlangauge as an intermediate linguistic system between learners' native language and the target language. It is suggested that the learner's language will show systematic features both of the target language and of the mother tongue and such language system is a mixed or intermediate one. Many researchers of second language acquisition (SLA) have studied learner's speech production of English vowels (Bohn & Flege 1990, 1992; Chang 2008; Ingram & Park 1997; Li 2004). Chinese learners of English often have difficulties with English vowels because there are some similarities in articulating the vowel sounds of these two sound systems.

The American English vowel system consist of 11 distinct vowels, /ι, I, ε, E, Θ, ℘, υ, Y, ο, □, A/ (Peterson and Barney, 1952). Mandarin Chinese is the official language used in Taiwan. The specific vowels are /ι, ε, y, υ, ο, A/, even though there are reports of variations in production of vowels in conversational Mandarin which reflect as many as 12 different vowel types (Flege, Bohn and Jang, 1997; Li and Thompson, 1981). The status of English as a foreign language in Taiwan may well influence on a speaker's linguistic performance due to the interference of mother tongue. As a consequence, it is reasonable to hypothesize that Mandarin Chinese speakers would demonstrate minimal difference, if any, in production of these vowels in comparison to American English speakers.

Vowel sounds may be said on a variety of pitches, but they are distinguished from each other by two characteristic pitches associated with their overtones (Ladefoged, 1993). One of them corresponds roughly to the difference between front and back vowels. The other corresponds to what we called vowel height in articulatory terms. These characteristic overtones are called the formants of the vowels. Due to the language transfer, it is predicted that the formant patterns of English cardinal vowels produced by Chinese learners of English would be similar to those of Chinese vowel quality. In the present study, we explore the acoustic nature of the suggested difference by directly comparing speech samples from American English and Chinese learners of English.

Pronunciation instruction in Taiwan mainly focuses on the audio-lingual approach: articulatory descriptions, diagrams and minimal pair drills are commonly used. Correction and analysis of students' pronunciation largely depends on the teacher's subjective auditory judgment. In fact, one of the effective ways to show the differences would be based on acoustic analysis from which accents can be decomposed into pitch, duration, vowel quality, vowel length, pause and the like. Therefore, this study also tries to diagnose and analyze students' pronunciation by examining the acoustic difference of English vowels between American English speech and that of EFL Chinese learners in Taiwan.

The research questions are proposed as follows:

1. What are the acoustic properties of English vowels and Chinese vowels?
2. What are the acoustic differences of English vowels produced by native English speakers and Chinese learners of English? To what extent are Chinese learners of English interfered by their mother tongue while producing English vowels?
3. What are the acoustic properties in vowels shown in the comparison between

female and male learners of English?

This study will carve up the discussion into three parts. The first part is the comparison of the American participants' speech with typical American speech, which aims at varying the validity of formant values for American speech. The second part is the presentation of the individual vowel quality of Chinese vowels as well as the comparison between Chinese and English vowel qualities. The third one is the interlanguage analysis of the Taiwanese participants' English speech with the American native speakers' speech. Finally, the implication of acoustic studies in EFL teaching of pronunciation is provided. It is hoped that this study can be shed new light on EFL pronunciation instruction.

Acoustic Features of English Vowels

Vowel quality is the acoustic property responsible for prominence distinctions at the lowest level of the prosodic prominence hierarchy in English (Beckman & Edwards, 1994; Bolinger, 1964, 1986; Liberman & Prince, 1977). In articulatory phonetics, vowels are characterized mainly in terms of three features: (1) the vowel height (2) the degree of backness and (3) the degree of lip rounding. Acoustic studies approach the characterization of vowel differently. "An acoustic analysis of vowels stresses the different formant configurations that are characteristic of each vowel. The relationship among the vowels can be examined by comparing their formant values (Olive, Greenwood, and Coleman, 1993). The high-low and front-back distinctions are represented by the first and second formants on the spectrogram (Fry, 1996; Olive, Greenwood, and Coleman, 1993). The first formant inversely reflects the high-low distinction. That is, lower the formant value, the higher the vowel. The second formant reflects the front-back distinction. If the formant value is high, the vowel is closer to the front position.

For front vowels, F1 becomes lower when the constriction in the oral cavity increases. /ι/ is the most constricted vowel. F1 increases as the tongue position gets lower. In addition, /ι/ has the highest F2 and /Θ/ has the lowest F2. The maximum separation between F1 and F2 occurs with the highest vowels, and is the smallest with the lowest. For back vowels, F2 is much lower and closer to F1 for the back vowels than for the front. The vowel /υ/ has the maximum tongue constriction and the lowest F1.

Regarding typical American speech, there are three sources of data: One is Ladefoged (1993), the other is Olive et al (1993), and another Stevens (1998). It is self-evident that these three data obtain rather similar formant values for each vowel.

Table 1. Reproduced from Ladefoged's typical vowel formant values. (1993)

	/ι/	/I/	/E/	/Θ/
F1	280	400	550	690
F2	2250	1920	1770	1660
F3	2890	2560	2490	2490
	/υ/	/Y/	/□/	/A/
F1	310	450	590	710
F2	870	1030	880	1100
F3	2250	2380	2540	2540

Table 2. Reproduced from Olive et al's typical vowel formant values. (1993)

	/ι/	/I/	/E/	/Θ/
F1	280	400	550	700
F2	2250	1900	1700	1650
F3	2750	2600	2500	2500
	/υ/	/Y/	/□/	/A/
F1	300	450	550	750
F2	850	950	1000	1100
F3	2400	2400	2500	2600

Table 3. Reproduced from Stevens' typical vowel formant values. (1998)

Male	/ι/	/ε/	/Θ/	Female	/ι/	/ε/	/Θ/
F1	270	460	660	F1	310	560	860
F2	2290	1890	1720	F2	2790	2320	2050
F3	3010	2670	2410	F3	3310	2950	2850
	/υ/	/o/	/A/		/υ/	/o/	/A/
F1	300	450	730	F1	370	600	850
F2	870	1050	1090	F2	950	1200	1220
F3	2240	2610	2440	F3	2670	2540	2810

Based on the above review, it is only Stevens' (1998) that provided data with different genders. To distinguish the gender difference in vowels, we take the values in Table 3 as the norm of American English vowels in this current study. Due to short of /□/, /I/, and /E/ sounds in this data, we added these three sounds from Peter Ladefoged's (1993). The modified list shown in Table 4 will be used as the baseline of typical American English.

Table 4. The typical vowel formant values of American English in this study

		Gender	[A]	[ε]	[ι]	[□]	[υ]	[I]	[E]	[Θ]
F1	Typical	M	730	460	270	590	300	400	550	660
		F	850	560	310	590	370	400	550	860
F2	Typical	M	1090	1890	2290	880	870	1920	1770	1720
		F	1220	2320	2790	880	950	1920	1770	2050

As for Chinese typical vowels, Chung (1996) claimed that in Southern Min dialect, there are six oral (/ι/, /ε/, /A/, /□/, /o/, and /υ/) and four nasalized vowels (ι∫, ε∫, A∫, □∫). Since the participants in this study is local Taiwanese, their home language is Southern Min dialect and official language is Mandarin Chinese. We chose five oral vowels /A/, /ε/, /ι/, /□/and /υ/ found in both Southern Min and Mandarin Chinese, and have a comparison with American English vowels.

Method

Participants

Eight participants were selected in this study. Four Chinese college students in the department of Applied Foreign Languages at Wu Feng Institute of Technology and four native speakers of English, who are teaching at Columbia Language School in Chia-yi, Taiwan. In Chinese group are two males and two females, aged between 20 to 22 years. In English group are two males and two females, aged between 30 to 40 years, who had been brought up and educated in the United States.

Recording Procedure

Before the session of recording, the participants were instructed the goal of the recording and how the recording would proceed. The reading material was read in the language labs at the Wu Feng Institute of Technology and Columbia Language School in Chia-yi, and recorded on a Compaq notebook with Praat software program and an attached microphone, placed at a distance of about 30 centimeters from the subjects' mouth. The student participants were first asked to read a set of eight English words, and then the other set of five Chinese words. For the group of native English speakers, they were asked to read a set of eight English words only. All of the participants were allowed to ask and practice the words they were not familiar with before the recording began. However, the students would not be corrected if they still mispronounced the unfamiliar word after they asked and practiced. The sample words are shown in Table 5.

Table 5. The sample English and Chinese words

English words	**Bot**tom	Bait	Beat	Bought	Boot	Bit	Bet	Bat
	/A/	/ɛ/	/ɩ/	/□/	/ʋ/	/I/	/E/	/Θ/
Chinese words	巴	背	必	播	不			
Pin-yin	ba	bei	bi	bo	bu			

The speech of participants was directly recorded into the computer. One file is allocated to a set of words for every participant. The analytical tool is Praat, software for the analysis of the properties of sounds.

Results and Discussion

In this section, American participants' speech is compared with the typical American speech, which will be considered as the reference and then compared the student participants' speech with it. The aim of the comparison is to demonstrate the different vowel space of the student participants from the typical American speech. Appendix A shows the details of duration, F1, F2, F3, waveform, and spectrogram for each sound: English: bottom, bait, beat, bought, bet, bit, bat, and boot; Chinese: 巴 (ba) , 背(bei), 必(bi), 播(bo), and不(bu).

(1) Comparison between student participants' speech and American speakers' speech

The average formant values of the typical American speakers' speech and American participants' speech are shown as Table 6.

Table 6. Comparison of typical American speech and American participants' F1 and F2 formants

		Gender	[A]	[ɛ]	[ɩ]	[□]	[ʋ]	[I]	[E]	[Θ]
F1	Typical	M	730	460	270	590	300	400	550	660
		F	850	560	310	590	370	400	550	860
	Participants	M	594	414	412	641	338	490	587	767
		F	782	454	377	740	496	586	538	780
F2	Typical	M	1090	1890	2290	880	870	1920	1770	1720
		F	1220	2320	2790	880	950	1920	1770	2050
	Participants	M	1209	2193	2079	1144	1051	2001	1839	1480
		F	1281	2216	1889	1198	1059	1955	1995	1867

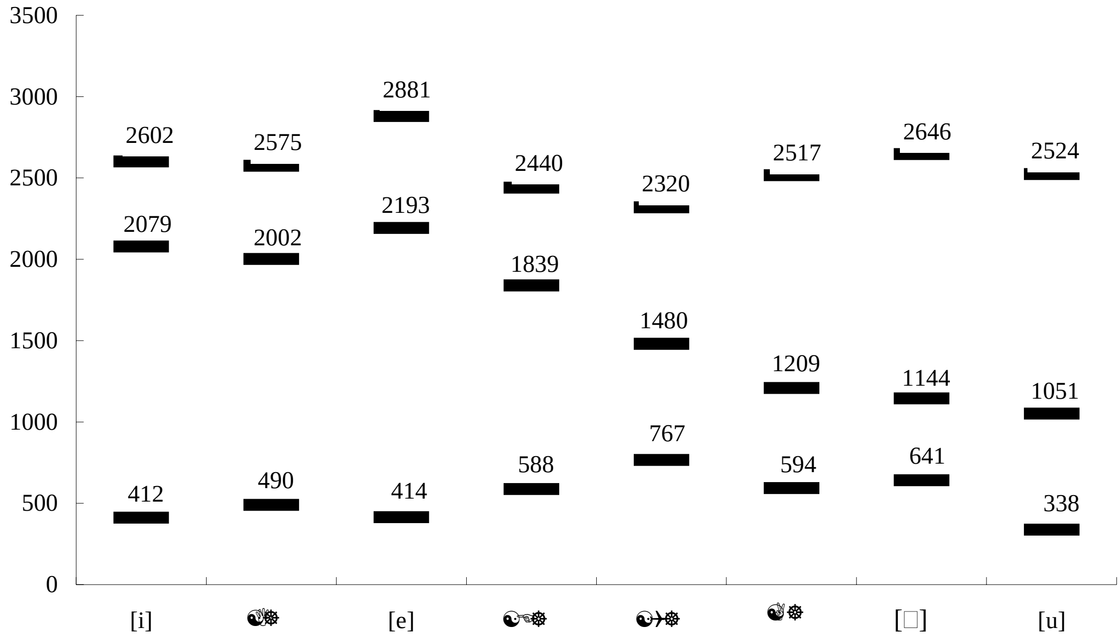

Figure 1. Male American Participants' frequencies of the first three formants in American English vowels

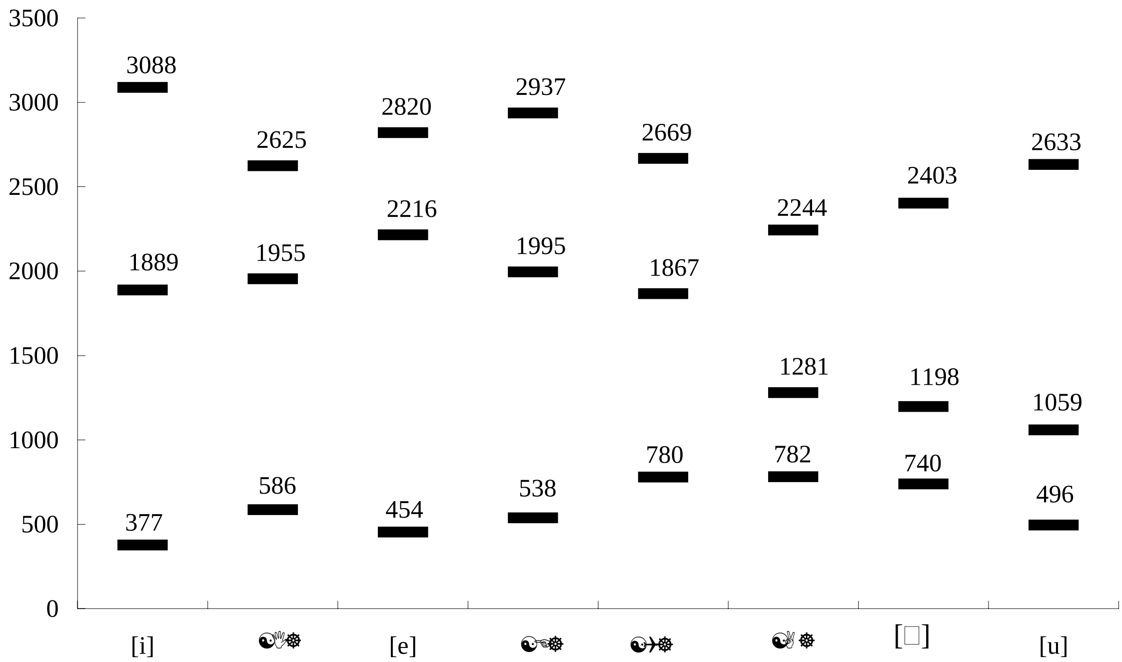

Figure 2. Female American Participants' frequencies of the first three formants in American English vowels

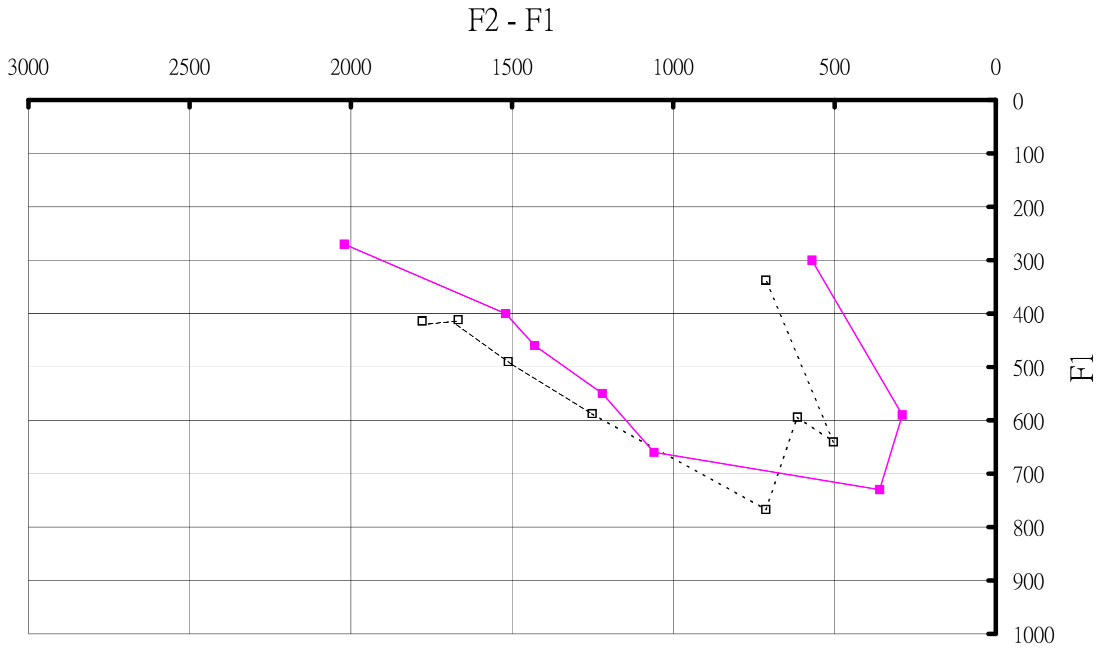

Figure 3. Comparison of typical male American speech (line) and American male participants' (dotted line) formant chart of eight English vowels.

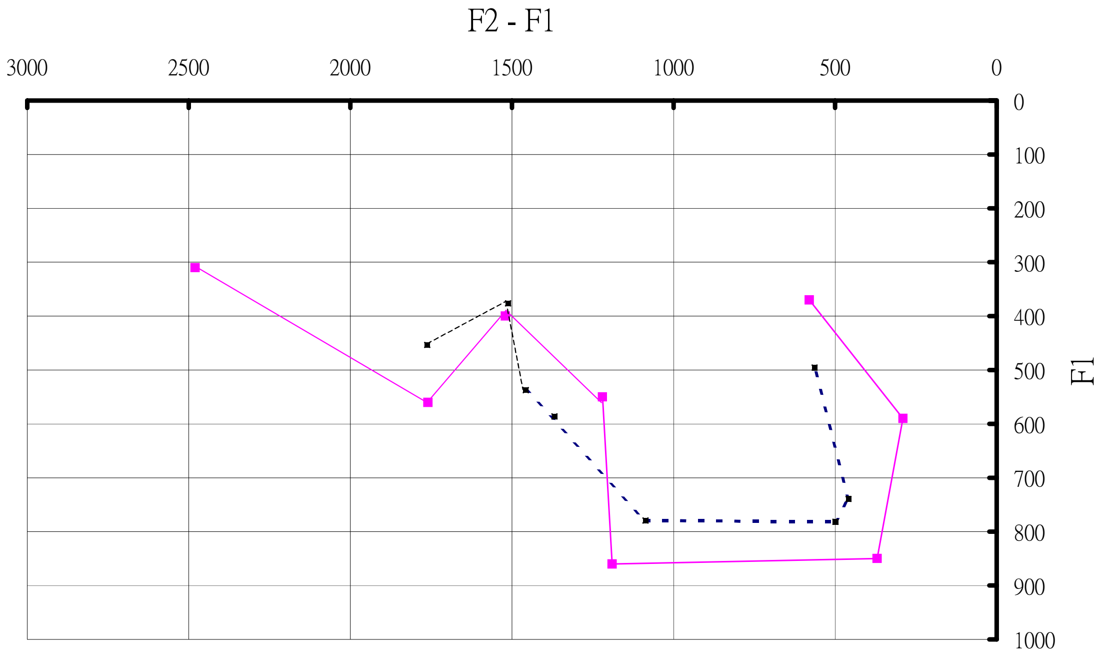

Figure 4. Comparison of typical female American speech (line) and American female participants' (dotted line) formant chart of eight English vowels

In figure 3, the male American participants' speech is rather similar to the typical American speech. Relatively speaking, the participants' speech is a little backward than the typical one. However, some differences can be observed in female American participants' speech shown in figure 4. Although the general pattern of vowel space (that is, like a shape of big mouth) is there, the formant values seem to be not that parallel. As Ladefoged (1993) mentioned that when two different speakers pronounce sets of vowels with the same phonetic quality, the relative positions of these vowels on a formant chart will be the same, but the absolute values of the formant frequencies will differ from speaker to speaker.

(2) Chinese Vowel Quality

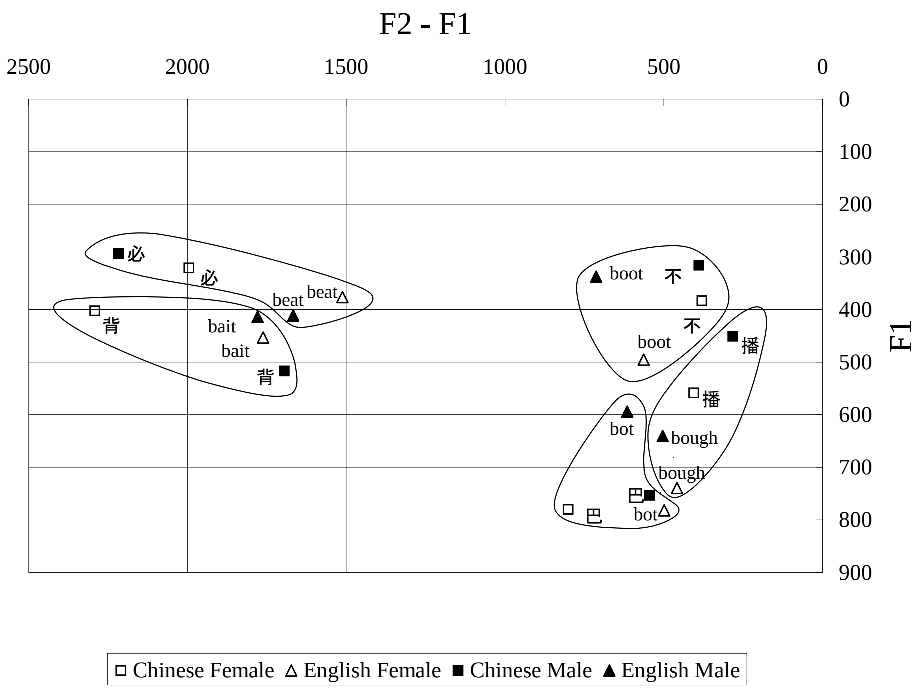

Figure 6. Comparison of Vowel Formants, [bA],[be],[bi],[b□],[bu]and 巴,背,必,播,不, in Four Groups: Chinese male and female students' participants and American male and female participants

In figure 6, it is interesting to note that the formant values of students' Chinese vowel, be it front or back, are generally lower and disperse than those of American speech. For example, F1 of 必 spoken by Chinese female is around 320 Hz while F1 of *beat* spoken by English female is around 380 Hz. For front vowels, F1 becomes lower when the constriction in the oral cavity increases. In other words, the vowels in Chinese are acoustically higher. When students learn English vowels, our prediction is that they may reference the similar vowels in Mandarin Chinese and Southern Min dialect and thus elevate the tongue position of English vowels.

(3) Comparison of American English and Chinese English

Prediction:

We predicted that the vowel quality of Chinese English is similar to that of Chinese instead of that of American English.

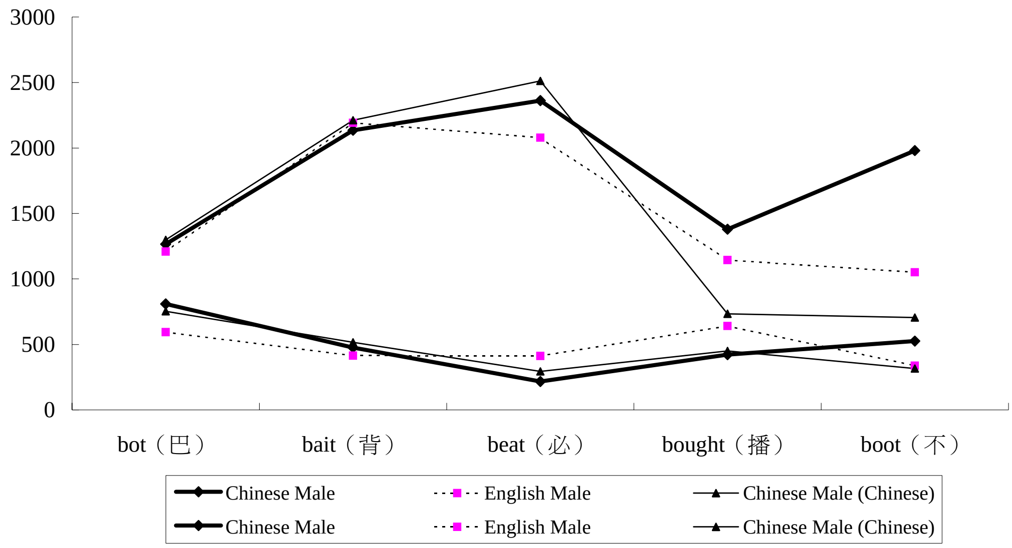

Figure 7. Male student participants' English speech (bot, bait, beat, bought, boot) (*heavy line*), Chinese speech (巴、背、必、播、不)(*line*) and male American participants' speech (bot, bait, beat, bought, boot) (*dotted line*)

Note. The upper lines are represented as F2 formant values. The lower lines are represented as F1 formant values.

To demonstrate the vowel differences in Chinese speakers' Chinese vowels, English vowels and American speakers' English vowels, the F1 and F2 formant values of the student participant speech and American speech are shown in figures 7 and 8. In figure 7, the male student participants produced Chinese five vowels almost in the same way as English five vowels in F1 formants. In F2, the patterns vary in *beat (必), bought(播)* and *boot (不).* The F2 values of *bought(播)* and *boot (不)* show more fronting than those of native speakers of English. In other words, they tended to front the vowel quality and mispronounced *bought* /□/ to *bot* /A/ and *boot* /u/ to *boat* /o/.

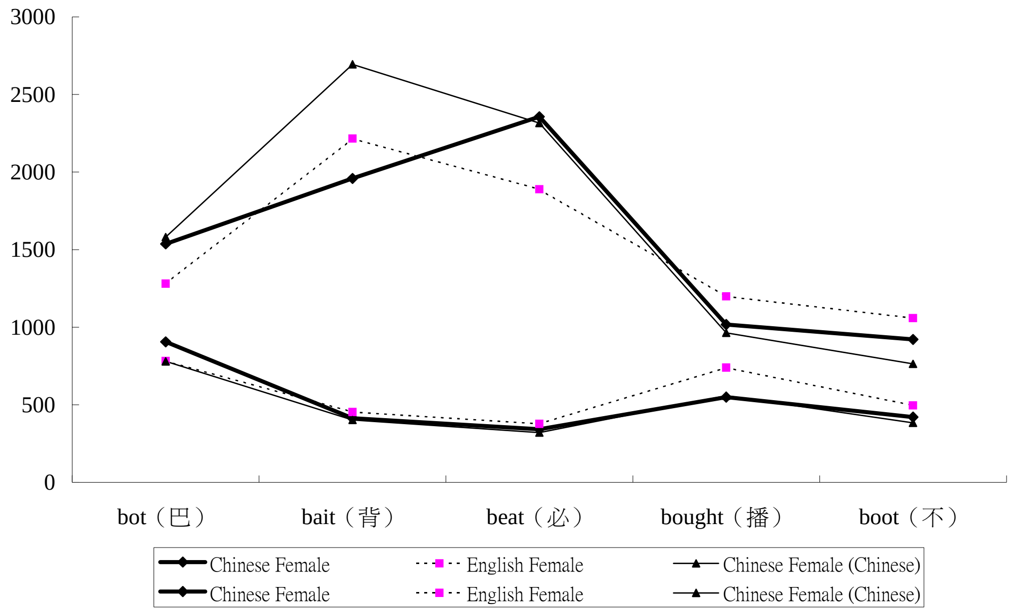

Figure 8. Female student participants' English speech (bot, bait, beat, bought, boot) (*heavy line*), Chinese speech (巴、背、必、播、不)(*line*) and female American participants' speech (bot, bait, beat, bought, boot) (*dotted line*)
Note. The upper lines are represented as F2 formant values. The lower lines are represented as F1 formant values.

In figure 8, the female student participants show a great impact of mother tongue interference on their English pronunciation of five cardinal vowels. That is to say, in F1, it doesn't show any difference for the female student participants to produce Chinese and English vowels. In F2, it also shows the same pattern as the above except the pair *bait* /ɛ/ and *背 (bei)*. It is observed that the F2 value of *bait* produced by the Chinese participants tend to be backward. They mispronounced bait/e/ to bat /Θ/ or bet /E/. The possible explanation would account for the vowel de-diphthongization of Southern Min dialect. It is commonly observed that Taiwanese Chinese has the tendency of shortening the vowels, such as [o] to [□], [ɛ] to [E]. The habit may also make it possible for shortening their Chinese English.

Implication and Conclusion

In this acoustic study, we found it strong visible evidence that the Chinese EFL students pronounce Chinese vowels and English vowels almost in the same way. They have the tendency of moving vowels higher and closer to the front positions. For most EFL teachers, the thing they concern most is how they help students get rid of mother tongue accent and become more English native-like. Based on the current study, it is suggested that "Chinese English" or "Taiwanese English" exist in such an

EFL context. We have to admit the fact that the impact of our first language interference in pronunciation is so enormous that we can improve it but the mission of getting rid of the accents seems not easy to be achieved.

One of the effective ways to improve students' pronunciation is to use the places and manners of articulation they have known and then apply them to their second language pronunciation. As Brown (2001) claimed, it is better for a second language teacher to be familiar with the learner's first language sound system. If a second language teacher has the knowledge of sound system of the learner's first language, they would be more capable of diagnosing their difficulties.

In addition, acoustic phonetics plays a role of learning second language pronunciation. According to the interlanguage hypothesis (Selinker, 1972, 1992), L2 learners produce an interim grammar while progressing to L2 grammar. The formant values will provide visible evidence to show the progress. The formant values observed from a learner could be the basis to evaluate whether the learner is making the progress in pronunciation. The plotted chart of vowel positions will be a diagnostic tool because it presents the solid evidence of students' pronunciation in comparison with the Standard English pronunciation. Teachers and students can clearly spot the distance from the problematic pronunciation of vowel to the typical one. The instructor can explain the physical evidence of pronunciation difference along with concrete suggestions of improvement.

However, showing the chart of vowel space to students seems not enough to help students improve pronunciation. How to transform the formant values into clear and meaningful pronunciation instruction is what EFL teachers should center on. In fact, most of the pronunciation materials rarely discuss the role of acoustic studies. As Celce-Murcia, Brinton and Goodwin (1996) suggested that one outgrowth of electronic technology worthy of special mention here is the computers with the speech spectrographic devices, which are similar to those developed for linguists studying phonetic features of a language. Adapted for the teaching of pronunciation to nonnative speakers, they visually display the pitch, length, and loudness of an utterance on a screen, thereby allowing teachers and students to focus on intonation, rhythm, word and sentence stress, linking and juncture, and degree of aspiration. The devices allow students to compare the visual display of their spoken output with that of a native speaker, receiving immediate objective feedback on their production.

Some studies support the above-mentioned arguments. Eskenazi (1999) suggested that visual display is more effective than oral instruction in terms of prosody. Learners would better understand how to raise or lower their pitch to match the target speech by listening to the native model and watching the visual display. Hardison (2003) found that using audiovisual feedback was a more efficient way to train learners to discriminate contrastive sounds between L1 and L2 than the audio-only method. Hardison (2004) further conducted another study on prosody learning through computer-assisted training with a real-time visual display of the pitch contours. The results revealed a significant effect of improvement in both prosody and segmental accuracy.

Therefore, we believe speech spectrographic devices hold much promise for the teaching of pronunciation. When combined with traditional classroom instruction, they may provide the key for working with learners whose pronunciation is severely fossilized and who thus need special instruction in how to adjust their speech habits and fine-tune their vocal apparatus to make their speech more intelligible to other English speakers.

In terms of limitation of this study, the data from the participants were unsatisfactory to some degree. For instance, the distance of vowel formants between the typical American speech and the American participant's speech was greater than we had expected. One reason is due to the individual difference while the other might be due to the weakness of experimental design. One-time reading and only two subjects may cause the result somewhat not that reliable. With regard to recommendation for further study, some directions are worth investigation: the English consonant quality, sentence intonation, the establishment of typical Chinese speech and the acoustic application to second language acquisition.

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Appendix A

Details of Duration, F1, F2, F3, Waveform, and Spectrogram for American Speakers' Eight Vowels and Chinese Speakers' Five Chinese and English Vowels

(1) American Speakers:

Eight English Vowels: /A/, /ε/, /ι/, /□/, /υ/, /I/, /E/, and /Θ/

Male 1

	E-M1- Bottom	E-M1-Bait	E-M1-Beat	E-M1- Bought
Duration	0.205	0.166	0.490	0.112
F1	456	345	274	539
F2	902	2203	2182	751
F3	2582	3054	2567	2638

	E-M1-bet	E-M1-bit	E-M1-bat	E-M1-boot
Duration	0.165	0.153	0.241	0.195
F1	584	414	698	231
F2	1874	2047	1448	1122
F3	2488	2560	2176	2459

Male 2

	E-M2- Bottom	E-M2-bait	E-M2-beat	E-M2- Bought
Duration	0.178	0.187	0.195	0.142
F1	732	483	549	742
F2	1516	2183	1975	1537
F3	2451	2708	2636	2654

	E-M2-bet	E-M2-bit	E-M2-bat	E-M2-boot
Duration	0.1778	0.08	0.266	0.138
F1	591	566	836	444
F2	1804	1956	1512	979
F3	2392	2590	2463	2589

Female 1

	E- F1- Bottom	E- F1-Bait	E-F1Beat	E- F1- Bought
Duration	0.233	0.419	0.253	0.373
F1	758	361	352	696
F2	1052	2418	2699	987
F3	2388	3158	3614	2409

	E-F1-bet	E-F1-bit	E-F1-bat	E- F1-boot
Duration	0.419	0.271	0.209	0.373
F1	361	483	663	401
F2	2418	2345	1730	1078
F3	3158	2927	2537	2562

Female 2

	E- F2- Bottom	E- F2-Bait	E-F2Beat	E- F2- Bought
Duration	0.184	0.207	0.373	0.253
F1	806	546	401	783
F2	1509	2013	1078	1409
F3	2099	2482	2562	2397

	E-F2-bet	E-F2-bit	E-F2-bat	E- F2-boot
Duration	0.183	0.103	0.161	0.138
F1	714	689	896	590
F2	1571	1564	2003	1040
F3	2716	2323	2800	2703

(2) Chinese Speakers

Five Chinese Vowels: 巴/A/、背/ε/、必/ι/、播/□/、不/υ/

Male 1

	C-M1-巴	C-M1-背	C-M1-必	C-M1-播	C-M1-不
Duration	0.251	0.291	0.297	0.308	0.262
F1	663	493	275	459	294
F2	1271	2099	2346	682	704
F3	2851	2815	3329	2890	2456

Male 2

	C-M2-巴	C-M2-背	C-M2-必	C-M2-播	C-M2-不
Duration	0.179	0.331	0.313	0.232	0.169
F1	843	541	313	443	338
F2	1324	2325	2677	785	707
F3	3016	3057	3425	2995	2764

Female 1

	C-F1-巴	C-F1-背	C-F1-必	C-F1-播	C-F1-不
Duration	0.311 sec	0.375	0.240	0.396	0.297
F1	541	397	288	523	367
F2	1410	2716	2938	916	719
F3	3324	3551	3786	3134	3002

Female 2

	C-F2-巴	C-F2-背	C-F2-必	C-F2-播	C-F2-不
Duration	0.407	0.445	0.309	0.369	0.219
F1	1019	408	354	594	400
F2	1752	2672	1695	1012	808
F3	3083	3248	3214	3291	3309

(3) Chinese English (Five English Vowels produced by Chinese speakers)

Chinese Male 1

	bot	bait	beat	bought	boot
Duration	0.184	0.179	0.158	0.179	0.168
F1	680	543	341	522	409
F2	1240	1949	2217	960	1040
F3	2669	2695	2991	2702	2592

Chinese Male 2

	bot	bait	beat	bought	boot
Duration	0.108	0.174	0.217	0.243	0.195
F1	937	410	93	323	641
F2	1292	2322	2506	1798	2920
F3	2523	2922	3324	3277	3626

Chinese Female 1

	bot	bait	beat	bought	boot
Duration	0.142	0.177	0.57	0.186	0.231
F1	776	350	306	498	377
F2	1354	2785	2966	945	731
F3	3220	3286	3647	3317	2731

Chinese Female 2

	bot	bait	beat	bought	boot
Duration	0.127	0.185	0.132	0.254	0.166
F1	1036	476	377	600	464
F2	1720	1132	1746	1089	1110
F3	3171	2645	2761	3288	3021